DEPARTMENT OF COMMER

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BUREAU OF FISHERIES
HUGH M. SMITH, Commissioner

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By HARDEN F. TAYLOR
Chief Technologist
U. S. Bureau of Fisheries

APPENDIX II TO THE REPORT OF THE U. S. COMMISSIONER OF FISHERIES FOR 1922

Bureau of Fisheries Document No. 919

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PRINCIPLES INVOLVED IN THE PRESERVATION OF FISH BY SALT.[1]

By Harden F. Taylor,

Chief Technologist, U. S. Bureau of Fisheries.

Contribution from the Fishery Products Laboratory, Washington, D. C.

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INTRODUCTION.

The art of preserving fish by means of salt is of great antiquity. It was practiced by the Phoenicians and Greeks and was brought to a high degree of perfection by the Romans. Mixed with spices, salt was used for the preservation of food on the shores of the Mediterranean and the outlying country in the time of Christ, reference being made in the Sermon on the Mount to a salt which has lost its savor, meaning a salt in which the spices have lost their aroma by evaporation. In the centuries following the art continued, both in the Occident and the Orient, to play an important part in world economy. Shakespeare put in the mouth of his most wonderful character, Falstaff, the words: "If I be not ashamed of my soldiers, I am a soused gurnet"[2]—a pickled gurnard, the gurnard being held in such light esteem that it was a term of contempt. Whether "sousing" or pickling made the fish doubly contemptible had better be left to the philologists to determine. Less than 25 years after Shakespeare wrote that play the Plymouth Colony landed in America and brought with

[1] Appendix II to the Report of the U. S. Commissioner of Fisheries for 1922. B. F. Doc. 919.
[2] King Henry IV, pt. 1, Act IV, Scene II.

them the arts of sousing and pickling fish. The descendants of the Pilgrims are still pickling fish around Cape Cod and particularly at Gloucester.

To a great many people it may seem that science has contributed little or nothing to the improvement of methods of preserving fish by salt. Perhaps this view is shared by a considerable number of people who are engaged in the business of salting fish. To them it may appear that salting fish is just salting fish, and "that's all there is to it." It may be admitted readily that science has not so pervaded and dominated the fish-pickling industry as it has other ancient arts, but it has contributed something and is capable of contributing a great deal more, and here lies the purpose of this paper. That purpose is to present the rationale of salting and pickling fish, so that the reasons for the various steps and modifications will be readily understood and appreciated, to the end that the art may be practiced more intelligently and successfully. It is a further purpose of this paper, by showing what the few attempts made by science have done for the art, to convince and persuade those on whom the industry depends for its existence and progress that science can be expected to do a great deal more than it ever has done if it is energetically studied and applied.

HOW SALT PRESERVES.

Salt preserves by extracting water. Spoiling is a series of chemical activities for which water is necessary; remove the water and spoiling is arrested. The removal of water by means of salt is in some senses a truer dehydration than actual drying in air, for changes of an undesirable sort take place in air drying that are never corrected, while salting may be done in such a way that few changes other than removal of water are brought about. The statement that salt preserves by extracting water is to be taken strictly and literally, for salt has no peculiar preserving or antiseptic quality, as many people seem to think. Things live, die, and putrefy in the sea, which is one-tenth saturated with salt. But by sufficient concentration salt, an otherwise almost inert, harmless substance, becomes a powerful preservative, merely because, if concentrated sufficiently, it extracts water.

The process of transferring water from one place to another, as from the inside of a fish to the outside, under the influence of concentrated solutions, is known to physicists and chemists as osmosis. This principle of osmosis is of almost universal application in nature and is used by men in the arts, but a good understanding of it is not common. By osmosis our food is taken from the intestines to the blood without any communicating opening. By osmosis oxygen is taken from the air into the blood without any leakage of blood. By the same principle the kidney tubules remove undesirable substances from the body while holding back all desirable substances. By osmosis the roots of plants select the necessary minerals from the soil. A weak sugar solution will readily ferment, but if made concentrated it destroys yeast and bacteria by osmosis and is therefore an excellent preservative of fruits. Salt is also a preservative by virtue of its concentration. Any other neutral mineral substance equally soluble would preserve in the same way that salt does, but salt happens to be the only one that the human palate and stomach will tolerate.

HOW SALT EXTRACTS WATER.

At the risk of appearing verbose the writer undertakes to elucidate the principles that govern osmosis, because osmosis is nearly the whole principle of salting fish. Without a knowledge of osmosis people may salt fish successfully by rule, but without such a knowledge it is quite impossible to understand the process.

If a thin animal skin or membrane separates two liquids and if the liquids are alike and of the same concentration, nothing happens. But if they are unlike and of different concentration, one or the other or both of the liquids will pass through the skin to the other side. This passage through the skin or membrane is called osmosis. Just what components pass through the membrane, in what direction, and how much depend on many circumstances. For the purposes of salting fish water is always the liquid, plus whatever is dissolved in the water. The dividing membrane is the skin of the fish and the membranous inclosures of the microscopic cells of which the substance of the fish is composed. We thus have water and salt outside, cell membrane between, and fish juice, or protoplasm, inside, and we desire to know what will happen and how we can influence the process to suit our needs. The quantity and direction of flow through the skin or cell membrane will depend on (1) the nature of the dividing membrane, and (2) the nature and quantity of the substances dissolved in the water on each side.

The nature of the dividing membrane will be considered first. Almost any substance can be made into a thin film or membrane. Such things as glass, tin-foil, and mica may be exceedingly thin, but are totally impermeable and therefore uninteresting in the present connection. But other membranes or films, such as parchment paper, gelatin films, animal bladders, and goldbeater's skins are permeable to a greater or smaller degree. Suppose pure water were on one side of a membrane and water containing dissolved salt on the other. If the membrane is perfectly permeable to all constituents, water will pass through to the salt solution and salt will pass through to the water, and these movements will continue until the two sides are alike and then stop. It is always the tendency for the two liquids to come to equilibrium, and they would do so if the membrane were perfectly permeable. Nearly all membranes, however, permit a freer flow of the solvent, in this case water, than they do of the solute (that which is dissolved), in this case salt.

If the membrane permits the water to flow but absolutely prevents passage of a dissolved substance, the membrane is said to be semipermeable. In the example taken above, of pure water on one side and salt solution on the other, if the membrane were semipermeable then the water would pass through to the salt solution, but the salt could not get through to the water. The level of the pure water would fall and that of the salt would rise. The difference in liquid level would exert a pressure called osmotic pressure. Ideally semipermeable membranes are not realized in nature, though some of the membranes in plants and animals approach ideal semipermeability while they are living. Ideal semipermeability with respect to particular dissolved substances has been achieved and is found in living organisms.

It is to be remembered that in case of semipermeable membranes the solvent will flow from the less concentrated to the more concentrated side of the membrane, so that if we wish to extract water we need only to make the outside more concentrated than the inside. If we wish to add water, we make the outside less concentrated than the inside; that is, we use pure water outside, as has sometimes been done unfairly to swell oysters and make them appear "fat."

It is also to be remembered that the degree of permeability of membranes does not necessarily remain unalterable. The permeability of the membrane can very readily be changed, as will be seen later. There is reason for believing, for example, that the permeability of fish to salt increases after death—for stale fish strike through more quickly than fresh fish—and that permeability increases at temperatures near the freezing point of water.

The tissues of fish consist mostly of cells. Each cell is a bag of semiliquid, like the white of egg. The surface of every cell either is or acts like a semipermeable membrane. If we surround the cell with water, the inside will be more concentrated than the outside and water will go in. If we surround the cell with strong salt solution, water will pass out to the salt. Some salt will also pass into the cell, which fact shows that the cell wall is not ideally semipermeable.

But what of the protein within the cell? Why does it not come out while the salt is going in? In order to answer these questions it is necessary to pass from a consideration of the nature of the membrane in osmosis to a consideration of the nature of the dissolved substance.

By a great many experiments it has been found that some dissolved substances never pass through membranes under any circumstances, while others will pass through some membranes. It is found that those which never pass through are also those which on drying out do not crystallize but shrink to a tough mass. They are called colloids. Examples of them are glue, albumen, gelatin, and soap. The smallest possible particle of these substances is comparatively large, too large, we may imagine, to go through the texture of the membrane. They are not only large of molecule but complex in structure. The bulk of animal bodies consists of colloids called proteins, dissolved in water. The other class of substances, those that may pass through membranes and which on drying out crystallize in regular geometrical shapes, are the crystalloids. Examples of this class are salt, sugar, and like substances. It is not to be supposed, however, that all crystalloids will pass with equal facility through any given membrane. Nearly all membranes are in some measure selective of particular crystalloids. The ideal semipermeable membrane permits none to pass, but as membranes degenerate from ideal semipermeability to complete permeability they permit more and more of these dissolved things to pass through.

The phenomena of osmosis having been briefly reviewed, one may readily perceive the importance of applying the principles to the salting of fish. Salt is brought in contact with the exterior of the cell. It dissolves in some of the moisture, forming a saturated solution. This solution is separated from the contents of the cell by a cell membrane which is more or less semipermeable. Water passes out of the cell to the salt and the processes of decay are stopped because of insufficiency of water. The membrane, not being absolutely semipermeable, permits some salt to enter and the fish remains salty. The contents left in the cell are proteins or the valuable food elements of the fish which, being colloids, are not permitted by the cell membrane to pass out. Thus water is extracted, salt enters, and the fish is preserved.

When the time comes to eat the fish the process is exactly reversed. The fish is bathed in pure water. The cell contents are more concentrated than the exterior, so water passes in. The cell membrane is to some extent semipermeable, so the protein does not escape, but the salt does. This exchange is carried to a point where the meat is again plump and a sufficient quantity of salt has been removed.

Thus by exposing the meat of fish to salt we have removed the water and caused some salt to enter the meat and have stored the fish. We have then by exposing the fish to water put water back in the cells and taken out the excess salt. The actual food material of the fish—the cell protein—is still where it was, for practical purposes unchanged. If every step has been scientifically correct we have at the end very nearly the fresh fish we had to start with. But there is the rub. At every turn it is possible to depart from the scientifically correct. The principles of osmosis here very briefly stated are the fundamentals of the art of salting fish. In all that follows there will be frequent occasion to refer to osmosis.

FACTORS AFFECTING PERMEABILITY OF FISH.

The preservation of fish by salt is practiced extensively in the cooler parts of the United States, but very little has been done south of Chesapeake Bay. The reason fish have not been salted in the warmer parts of the country is that the process has not been satisfactory. Repeated efforts to salt alewives on the St. Johns River in Florida previous to 1920 uniformly resulted in failure. In 1918 research on this problem was undertaken under the immediate direction of the writer. The results of a part of this program were published.[3]

The hypotheses which guided this work were somewhat as follows: During the course of "striking through" the fish two things are happening—(1) the flesh is breaking down by autolysis (a process to be explained later) and (2) the salt is penetrating the flesh. Salt arrests autolysis when it arrives, but considerable damage may be done before the salt has reached the innermost parts of the fish. Now, these two processes—salt penetration and autolysis—are running a race, so to say. If the salt penetrates to the innermost parts before autolysis has destroyed them, the salt wins the race and the fish is saved. If before the salt can get to the innermost parts they have been decomposed by autolysis to an intolerable degree, then autolysis wins and the fish spoils. High temperatures accelerate both processes, but while accurate measurements have not been made we know

[3] Tressler, D. K.: Some Considerations Concerning the Salting of Fish. Appendix IV. Report of the U. S. Commissioner of Fisheries for 1919, 55 pp. B. F. Doc. No. 884. Washington, 1920.

by practical experience and by experiment that at a sufficiently elevated temperature the fish will invariably spoil if blood be present. Now, to make certain that the race mentioned shall always be won by the salt, we may do one of two things, namely, retard the rate of decomposition or accelerate the penetration of salt. Working at a lower temperature is the only practicable means of retarding decomposition, but since we desire a method suitable for warm climates it is necessary to accelerate penetration of salt. How can the salt be caused to penetrate fish more rapidly?

The physiologists have shown that in living animals compounds of calcium, barium, and magnesium have a marked effect in retarding or arresting penetration of membranes. By examination of numerous analyses of commercial brands of salt it was found that the salts of calcium and magnesium are those nearly always present as impurities. A few of these analyses are given herewith:

ANALYSIS OF VARIOUS SALTS FOR CURING FISH.[1]

Substances present.	Turks Island salt.	Trapani, Italian salt.	Iviza, Spanish salt.	Diamond Flake, domestic salt.	Leslie Velvet Grain, California salt.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Sodium chloride	96.52	95.82	98.05	99.78	99.96
Calcium chloride	....	.32	.49	....	....
Calcium sulphate	1.53	....	....	.37	.067
Magnesium chloride	1.20	1.19	....	.00	.00
Magnesium sulphate	.80	1.75	.80	.00	.010
Sand, etc	.13	.15	.06	.00	.022

[1] These figures represent analysis of single samples of each brand taken in the market and are not averages of numerous samples. Not only is some variation in manufacture unavoidable, but the chemical determination of such small quantities of impurities is subject to small errors. Therefore it should not be expected that any purchased lot of salt would conform exactly to the composition shown here. The figures represent in a general way the degree of purity that can be expected.

By appropriate methods of measuring the rate of penetration of salt into fish it was found that if absolutely pure salt is used a very rapid penetration is obtained, but that even small additions (from ½ to 5 per cent) of these salts of calcium and magnesium cause a very pronounced retardation of penetration. For example, by appropriate methods of analysis it was found that pure salt penetrated as deeply in less than five and one-half days as did salt containing 1 per cent calcium chloride in nearly seven days. Similarly, a salt containing 4.7 per cent magnesium chloride penetrated no farther in five days than pure salt did in three. In order to bring about a much more rapid penetration of the tissues then, we have but to obtain a salt free from these impurities. The time gained by the use of pure salt enables fish to be salted at a much higher temperature and yet not spoil. Fish were salted in an incubator room in Washington at a temperature of 90° F. at first, rising to 100° F.—the hottest summer weather. No unpleasant odor developed, and the fish upon being cooked and eaten were pronounced excellent.

There was a further and somewhat unexpected difference between the effects of pure and impure salts. The flesh of the fish salted by impure salt is white, opaque, or chalky in appearance and much harder or firmer in consistency; that of fish salted with pure salt is translucent and somewhat yellowish and much softer. While the former white, firm fish is the customary quality demanded in commerce, there are strong reasons for believing the softer and yellowish fish produced in pure salt to be superior. There is reason for believing that the whitening of the fish in impure salt is explained by the fact that the calcium coagulates the protein, just as heat by coagulating egg white causes it to be white and firm. But where there is no calcium in the salt the protein retains its natural translucency and yellowish color. The calcium in impure salt is retained by the fish, a matter that will be discussed later under the subdivision on flavor of salted fish.

While no investigations appear to have been made on the influence of temperature on the permeability of fish flesh, investigations have been made on a great variety of other living things, so that it is probably safe to generalize cautiously regarding such influences on fish. Osmotic pressure varies, approximately, as absolute temperature.[4] That is, if we double absolute temperature osmotic pressure is doubled, other factors being held constant. The range from 32 to 100° F. within which fish salting is usually done is, on the absolute scale, rather narrow (491.4 to 559.4° A.), so the maximum variation due to this cause would be about 14 per cent. It is, however, a common experience in pickling fish that the warmer the temperature the more rapid the striking through, a difference too great to be accounted for by temperature variations of osmotic pressure. The cell membrane itself must change. Whether any more free permeability caused by warm temperature is permanent after the fish is chilled again is not known, but the question would be well worth investigating. Cold, when in the neighborhood of freezing, also promotes permeability, as has been proved by various experiments. It is quite possible that fish chilled to a point near freezing (as in the mild curing of salmon) would strike through much more quickly than fish at the customary warmer temperatures. This matter also should be investigated.

Stale fish—that is, fish whose cell membranes have "died"—are more permeable than fresh fish. Some fish were held in the laboratory all day at a temperature of about 75° F. and toward night were salted in pure salt and put in an incubator at 100° F. By the next day they were struck through. The combination of stale fish, high temperature, and pure salt brought about extraordinarily rapid penetration.

At this point mention should be made of another effect of salt upon the protein constituents of fish. Strong solutions of salt precipitate certain protein substances, different substances falling out successively from a mixture of dissolved proteins as the concentration of salt is increased. The nature of the proteins is not altered by this precipitation, for upon replacement of the salt solution with fresh water the proteins redissolve and appear to be restored to their original condition. Salt thus causes a temporary precipitation or fixation of proteins in fish, to a certain extent hardening the tissues and reducing the likelihood of changing. Not only does quite pure salt penetrate the fish more rapidly, but when the time comes to cook the fish it is found to soak out more rapidly also. Practical experiments in the experimental kitchen of the Bureau of

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[4] Absolute temperature is based on absolute zero, the point of no heat, or absolute cold, which is −273° C. or −459.4° F. If we use degrees the same size as Fahrenheit's degrees, then 0° F. is 459.4 absolute; 50° F. is 459.4 + 50=509.4 absolute, etc.

Fisheries indicate that fish preserved in very pure salt soak out in from a third to a half the time required by fish preserved in crude salt.

What is the practical lesson of this work? It shows that by the judicious selection of salt, not on the basis of its cheapness but on the basis of composition, one can produce a salt fish of almost any desired quality. If salting is to be done in very warm weather it will be necessary to use the purest grade of salt to secure very rapid penetration. In this way a soft, yellowish fish of excellent quality is obtained. Where weather is cool enough to permit, a salt containing more calcium and magnesium may be used, in which case a whiter and firmer fish will be produced.

Can these very pure salts be obtained commercially? Several brands of salt of the highest degree of purity are available both on the east and west coasts and at a cost not much above the price of cruder salt. In many cases the single item of fish saved that might otherwise spoil will repay the extra cost of pure salt, to say nothing of the improvement in quality of the salt fish.

FLAVORS OF SALT FISH.

The calcium and magnesium are taken up by the protein in the cells and held, not coming out when the fish is soaked. Now, these impurities, particularly calcium, have an acrid taste and greatly accentuate the "saltiness" of salt. Pure salt is not so "salty" to the taste as crude salt. If the calcium is held by the tissues at the time of soaking out while the salt is removed, then after soaking there is a much greater amount of calcium present in proportion to the amount of sodium than there was in the original salt and a correspondingly more acrid "salty" taste. It is therefore necessary to soak out fish much longer or until they are "flat" if they have been cured with crude salt, while with pure salt they may be soaked out until they suit the taste, after which they retain their original flavor.

Certain improvements in the flavor of fish have been noted after they have been salted by improved methods. The fish variously known as mud shad or gizzard shad (*Dorosoma cepedianum*) is plentiful in certain parts of the country but is held in very low esteem because of its muddy, unpleasant flavor. After being washed free from blood and salted in pure salt this unpleasant flavor disappeared and the fish compared favorably with fish commonly more esteemed. The muddy taste of the carp and other fish from muddy ponds and streams is believed by some to be caused by species of Oscillatoria, a blue-green alga growing in the slime of the fish; by others it is believed to be humic acid derived from the mud. Perhaps the two views could be entirely reconciled, but the actual chemical compound or compounds responsible for the unpleasant flavor seems to be removed by the brine.

It is not difficult to understand how the alteration of taste may be brought about by salting. The main bulk of the fish, pure protein and pure fat, is believed to be tasteless and odorless. The substances which give rise to taste are free fatty acids (decomposition products from fats), amino acids (decomposition products of proteins), highly odoriferous *methylamines*, and various waste materials classed by the chemist as *purines*. The absolute quantities and also the relative proportions of these materials vary from species to species of fish, and they even change in the same individual fish as staleness develops. Now, most of these odoriferous substances are soluble in water or brine, and after the salting process would be found in the brine. They are not replaced when the fish is soaked out. It might therefore be anticipated, as has actually been found, that the fresh fish, disagreeable because of the presence of strong substances, are rendered sweet by the removal thereof in the salting process.

If this lead were followed in detail, it is quite possible that salting would turn out to be the best method of utilizing fishes that are of a rather poor edible quality when in the fresh condition. This aspect of the matter deserves particular attention of the canners. Many species of fish of great abundance might in time be profitably packed if the flavor were inviting. With highly improved technique in salting, the undesirable flavors might be removed by curing and soaking out before canning. This process would be unthinkable on the basis of the customary salting methods where there is in the end an excessive saltiness or flatness of flavor, but the mild, sweet fish prepared by improved technique and pure salt is a much more promising possibility for canning.

DRY SALTING AND BRINE SALTING COMPARED.

The next question taken up in the investigations referred to was that of the relative merits of the application of the salt to fish in the dry state and as a concentrated brine. In the Chesapeake Bay region the herring are usually pickled in brine. By a strict comparison of the two methods it was found that there is developed a smaller quantity of the products of decomposition—the amino acids—when the salt is applied dry. Not only this, but it was also found that salt applied in the dry condition penetrates the fish more rapidly.

Among the products of protein decomposition are amino acids. A determination of amino acid nitrogen was taken as a measure of decomposition—the more of the amino acid nitrogen present the greater the amount of decomposition. This being true, the following table, summarized from Tressler's results, will show the superiority of dry salt over strong brine for preserving fish.

Amounts of Amino Acid Nitrogen Formed Per Kilogram of Fish at Different Temperatures.

Method of salting.	Temperature.	Amount of amino acid nitrogen per kilogram of fish after—					Condition at end of salting period.
		19 hours.	67 hours.	5 days.	7 days.	9 days.	
	° F.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	
Dry salted	63	0.078	0.083	0.085	0.085	0.119	Good.
Brine salted	63	.089	.129	.135	.183	.234	Do.
Dry salted	70	.084	.086	.098	.097	.126	Do.
Brine salted	70	.100	.165	.158	.190	.292	Do.
Dry salted	75.5	.077	.092	.099	.104	.134	Fair.
Brine salted	75.5	.102	.186	.179	.228	.316	Do.
Dry salted	80	.074	.086	.119	.141	.158	Do.
Brine salted	80	.086	.189	.210	.300	.383	Spoiled.
Dry salted	87	.076	.089	.159	.195	.208	Do.
Brine salted	87	.097	.244	.266	.377	.510	Do.
Dry salted	93	.065	.105	.151	.193	.236	Do.
Brine salted	93	.080	.238	.320	.465	.666	Do.

It is seen that the brine-salted fish consistently undergo a greater decomposition than those salted with dry salt, as shown by the abundance of decomposition products, amino acids. The average excess of amino acid nitrogen in the six lots pickled in brine over the six lots in dry salt is 51 per cent, a very material difference. It will be noticed in the last column of the table that spoiling of fish pickled in brine takes place at a lower temperature than it does in dry salt. Fish were satisfactorily salted in dry salt at 80° F., but at this temperature fish pickled in brine spoiled.

To complete the evidence in favor of using dry salt, the following table from the same paper shows the rate of penetration of salt into squeteague when applied dry in comparison with brine:

PENETRATION OF SALT.

Method of salting.	Section of fish.	Percentage chlorine in dry sample after—			
		1 day.	4 days.	7 days.	10 days.
Dry salted	Outer layer, from surface to a depth of ½ centimeter.	9.8	16.2	19.6	19.5
Do	Inner layer, from ½ to 1 centimeter below surface.	2.6	11.0	16.0	18.7
Brine salted	Outer layer, as above	8.4	15.3	17.3	17.8
Do	Inner layer, as above	1.8	8.3	12.2	15.7

What is the reason for the superiority of dry salt over strong brine or pickle, especially since the dry salt very shortly forms its own pickle? In answer to this question it is necessary to refer to the principles of osmosis. It was shown that the flow of water is from the less concentrated to the more concentrated. The relative concentrations govern the direction of flow and also the rate or quantity of flow. Salt is going into the fish and water coming out. If brine is used, it is losing some of its salt which penetrates the fish and is being diluted with water which is coming out. This process rapidly brings the contents of the cells into equilibrium with the brine; that is, with the film of brine immediately in contact with the fish. Stirring as usually done may cause a momentary increase of penetration by removing the film of dilute brine adjacent to the fish, but we may imagine that a new dilute film forms again very rapidly. If instead of brine dry salt is placed in contact with the fish very material differences are at once apparent. Part of the salt dissolving in the free moisture forms strong brine, which begins its extraction of water from the fish. The water coming from the fish is not able to dilute the adjacent brine, because some of the excess of dry salt present immediately dissolves, and thus assures saturated brine at all times. It should also be obvious that since the very purpose of using salt on fish is to extract water the addition of water at the beginning simply supplies just so much water to the salt and satisfies the affinity of salt for water to that extent. The water should come from the fish and not elsewhere.

To put into words the conclusions from this section of the paper, when salt is applied dry to the fish there is a more rapid penetration of salt, less decomposition of fish, and it is possible to preserve fish at a higher temperature. The superiority of dry salt over brine resides in the fact that the brine in contact with the fish is not permitted to be diluted if salt is present in crystalline condition.

LOSS BY FISH OF NUTRIENTS IN BRINE.

The liquid that comes from fish during the salting process is not pure water, as every fisherman knows, but contains a quantity of material derived from the fish. Most of the nitrogenous matter found in brine represents just so much good food gone to waste and just so many pounds of fish that might have fetched a good price gone overboard. The quantity of protein that escapes into the brine is highly variable, for reasons that will appear later. That some idea may be had of the magnitude of the loss of fish substance in brine the following figures are given. These figures were obtained in the course of investigation on the recovery of valuable materials from old brine:

LOSS BY FISH OF NUTRIENT MATERIALS IN BRINE.

Brine.	Grams dry protein per liter of brine.	Avoirdupois ounces per gallon.
Rockfish brine from Alaska	29.30	3.9
Herring brine from Gloucester	34.80	9.8
Cod brine from Gloucester	73.30	4.6

Since all the nitrogen in the brine was calculated as protein, these figures are undoubtedly too high; but the bulk of the nitrogen is certainly of protein origin, so the figures may be taken to illustrate the point made. If we assume fresh fish to be 75 per cent water and 25 per cent dry protein and express the results in customary units, the figures show the equivalent amount of food-fish flesh dissolved in brine to be 15.6, 39.2, and 18.4 ounces, respectively, or from 1 to $2\frac{1}{2}$ pounds to the gallon of brine. Bitting[5] calculated the losses in the curing of codfish as follows: Loss of weight in dressing, 40 per cent; loss in salting, 40 per cent of what remained after dressing; drying on flakes, 9 per cent of the salted fish. The 40 per cent of the dressed fish contains besides water much protein or valuable nitrogenous food. It would certainly seem to be worth our while to examine into the causes of this loss and to prevent or salvage it if possible.

How does this protein get out of the fish? It was said above that protein is a colloid and that colloids do not diffuse through membranes. A small amount must come from the blood and from the cut surface on the fish, but most of it will probably be found to come from the interior cells by a process not yet investigated. We do know something directly about autolysis, however, the great enemy of the fish dealer, which liquefies the contents of fish flesh, and we have every reason to believe that if autolysis were stopped the losses of protein into brine would be reduced to a minimum. What is autolysis and how does it do its damage?

[5] Bitting, A. W.: Preparation of Cod and Other Salt Fish for Market. U. S. Department of Agriculture, Bureau of Chemistry, Bulletin No. 133, 63 p. Washington, 1911.

Protein, the colloid, can not pass through an osmotic membrane, but proteins can be decomposed into simpler substances which readily dissolve and pass through. The agency which breaks down protein into these simpler substances is called an enzyme, and protein must always be so liquefied or digested by enzymes before it can be absorbed through membranes; hence the necessity of digestion in the stomach of animals preparatory to absorption of food through the intestines. Now, animals, including fish, require a certain amount of new protein to support the body activities, which, failing, the animal would immediately perish. But the hazards in the existence of any animal often make it obligatory to do without food for a shorter or longer period. If the stomach became empty because of temporary shortage of food or an injured mouth, the animal would die unless special provision were made to supply protein from some other source. But nature has provided a means whereby the proteins in the less important parts of the body can be used for the time being to support the activities of the absolutely necessary vital parts. The stored protein is within cells and could not possibly be carried by the blood stream to the point of need unless it could get out. So there is in each cell stored along with the protein some enzyme ready in case of threatened starvation to break the protein down into simpler substances which penetrate outward into the blood for transportation to the point of need. Fish may thus live for a time at the expense of their own bodies.

These enzymes, present in every part of the fish, while almost an absolute necessity to the living fish, become the greatest enemy of the dead fish, for they soften and liquefy the cell contents, cause unpleasant tastes and odors, and permit the contents to escape from the cell into brine. The proteins could not escape as long as they were proteins, but when they are broken down by autolysis into simpler substances the latter rapidly diffuse into the brine and are lost. This at least is the hypothesis, supported by some facts.

What factors promote autolysis and what factors oppose it? Warm temperatures promote it directly. A temperature sufficiently high to destroy the enzyme stops it. Low temperatures retard it directly.

If cells are ruptured, as they often are by rough handling of the fish, autolysis rapidly decomposes the protein, and for this reason every bruise received by the fish during capture and subsequent handling results in the loss of so much protein during salting. A bruise on a fish has about the same effect as does a bruise on an apple, promoting rapid decomposition. Perhaps if the bruised fish turned brown, as the bruised apple does, the fisherman and packer would be more careful in the handling of their fish.

Factors that increase permeability of membranes seem to promote autolysis. Low temperatures seem to increase the permeability of the cells, so that fish that have been chilled decompose more rapidly on being warmed than fish that have never been chilled, though as long as the fish remain on ice the low temperature may prevent the enzymes from doing their work. It is as if increased permeability increases the escape of the enzymes, and that once escaped they play havoc if temperature conditions are allowed to become favorable. The optimum temperature for autolytic activity is about human body temperature, 98° F. The autolytic enzymes act under a slightly acid condition. In neutral or alkaline medium they act very little, if at all. It has been noticed by various investigators that autolysis does not begin until two to four hours after death. During rigor mortis there is a decided development of acid that may very materially promote autolysis. It may therefore be that salting fish immediately after capture would strike through the fish before autolysis gains any headway. It may be possible, also, to take advantage of the removal of soluble products by brine in the salvaging of fish on the point of spoiling. Fish that have been held a long time are soft and of a disagreeable odor, because autolysis and possibly some bacteria have decomposed the tissues to some extent.

One might reasonably expect research to show that if rapid penetration is secured by means of pure salt the amino acids and other sour or disagreeable substances in stale fish resulting from autolysis would be removed by changing brine a few times, leaving the fish in a condition quite wholesome and fit for food. It is, of course, not intended here to encourage the practice of holding fish until they are bad and then salting them, but it is recognized that it is in the public interest neither to destroy food that can be used nor to market fish unfit for food, and it is recognized as legitimate and desirable to develop a means of saving fish whenever they have, through the unavoidable exigencies of the fishing business, come near to spoiling.

It would not be profitable to present this complicated subject any further here. Enough has been said to show that the loss in salting fish by solution of protein in brine is very great. Some discussion has been presented which will serve to show that losses of this kind are preventable, to point out the probable direction in which the remedy for this great loss will be found, and also, we hope, to assist in convincing the skeptics that scientific work on this aspect of the salting process would be worth while. It is of the greatest importance that research work be undertaken for the purpose of discovering the conditions under which the cell proteins are digested and pass out and for ascertaining the conditions under which these processes may be arrested. Specifically, such questions as follow should be answered: Once the permeability of cells has been increased by abnormally high or low temperature, does this increased permeability persist after a normal temperature has been restored? When autolysis is set in action by a bruise, do autolytic enzymes affect only the part bruised or do they escape and attack the uninjured cells, destroying them also? To what extent does the acid of rigor mortis accelerate autolysis, and can this acceleration be prevented by early application of salt? To what extent is loss of soluble material in brine due to rough handling and to what extent to other factors? Can advantage safely be taken of the removal of products of protein decomposition by brine to salvage fish that are on the point of spoiling?

INFLUENCE OF METHOD OF CLEANING FISH ON SALTING.

In the various processes of salting or pickling fish the fish receive no preliminary treatment, or they may be gibbed, beheaded, split through belly, split through back, or cleaned perfectly by being cut open, scraped, and washed before the salt is applied. By what criteria can we judge the merits of these various methods? The best way to answer this question is: Other conditions being held constant, which method or methods of cleaning result in least decomposition during the salting process?

A series of trials was made by cleaning the fish by the various methods and salting them by the same process and determining the amounts of amino acid nitrogen developed. Two sets complete were tried, one consisting of one sample each cleaned by the various methods and held at a temperature of 79° F. during the salting process; another set similar to the preceding but held at 88° F. during the salting process. Both temperatures are high for salting fish, and the test is correspondingly severe. The results are shown in the following table, which is abbreviated from the paper by Tressler:

DEVELOPMENT OF AMINO ACID NITROGEN IN FISH CLEANED IN VARIOUS WAYS.

[Fish salted four hours after capture, with Diamond Flake salt containing 99.78 per cent sodium chloride; salting period, nine days.]

Method of cleaning.	Average temperature of salting.	Amino acid nitrogen formed during salting period per kilo of fresh fish.	Condition of fish at end of period.
	°F.	*Grams.*	
No cleaning, salted round	79	0.77	Badly spoiled, bloated.
Pipped	79	.63	Spoiled.
Head cut off, abdominal cavity split open, viscera, except milt and roe, removed.	79	.68	Do.
Cleaned perfectly, milt and roe removed, kidney and membranes scraped, and all blood washed out.	79	.37	Excellent condition.
No cleaning, salted round	88	1.12	Badly spoiled, bloated.
Pipped	88	.76	Badly spoiled.
Head cut off, abdominal cavity split open, viscera, except milt and roe, removed.	88	.82	Do.
Cleaned perfectly, milt and roe removed, kidney and membranes scraped, and all blood washed out.	88	.47	Excellent condition.

Since amino acid nitrogen indicates decomposition, the conclusions from this table are entirely obvious. Only those fish were successfully salted at temperatures of 79 and 88° F. which had been thoroughly cleaned and from which all blood had been removed. While these high temperatures were chosen for the test because severe tests bring out differences in a more striking way, the differences will still exist even at lower temperatures and manifest themselves in the poorer or better quality of product. Now, it may be either the blood or flesh, or both, in which the decomposition takes place. Since the perfectly clean fish decompose only slightly, it may be that only the blood decomposed in such cases as those given in the table, and that the decomposed blood pervading the otherwise sound tissue gave the appearance and odor of decomposition to the whole fish. On the other hand, it is possible that the enzymes in the blood when present operate to decompose not only the blood proteins but the tissue proteins also. However, this may be, the indisputable fact remains that if fish are to be salted in very warm weather it is absolutely obligatory that the blood be removed. The blood can not be removed by mere eviscerating and rinsing in water. The kidney, a very bloody organ inclosed by a membrane against the backbone, must be scraped out before the fish is washed. If fish is cleaned in this manner and salt of a very pure quality applied in the dry condition, it is astonishing not only what severe temperatures it will stand, but also how excellent it is when cooked.

IMPROVED METHOD OF SALTING FISH ESPECIALLY FOR WARM WEATHER.

Several factors have now been shown to have a marked influence on the quality of fish pickled in salt, namely, care in handling before salting to prevent bruises, use of salt free from calcium and magnesium (less than 1 per cent total impurity), packing in dry salt, and thorough cleaning and removal of kidney and blood. By combining all these factors into one method highly satisfactory results under the most adverse conditions have been obtained.

A trial of the method was made in the herring season of 1920 (March, April, and May) on the St. Johns River, Fla. This region was selected because it offered a combination of the conditions sought. The climate is excessively warm, and there is an abundance of fish (alewives) adapted to preservation by pickling in a region where an industry might well be built up and where repeated efforts to salt fish in the past had failed. Accordingly, the interest of local fishermen and dealers was enlisted to cooperate in the undertaking, and an experienced fish packer from the Chesapeake Bay region was sent to Florida, after he had been thoroughly instructed in the technology of the process, to try salting by the proposed method on a small commercial scale.

The details as conveyed to the fishermen for handling the fish were: (1) Avoid (*a*) bruising the fish in removal from gill nets, (*b*) walking on, and (*c*) piling deep in boats; (2) salt as soon as possible; (3) wash and scale in cold water; (4) behead and eviscerate and (*a*) scrape out kidney or (*b*) split nearly through to the back and lay open; (5) wash in weak brine to remove all traces of blood; (6) rub with fine salt of a high degree of purity and pack backs down in a barrel, leaving fish lightly covered to form their own brine; (7) after they have been struck through pack down and add other fish of the same lot to fill barrel; and (8), in conclusion, (*a*) head up barrel and pour saturated brine into bunghole to cover fish for storage, or (*b*), if to be sold for consumption at once, take out of the brine and rub in fine dry salt, then pack in sugar barrels or other light containers and ship immediately.

The results fully justified expectations in every way. The fish were preserved successfully, and none that had been handled in the prescribed way spoiled. In eating qualities they were pronounced as good as or better than the best commercial salt herring from the Chesapeake Bay region. In order to test the absolute necessity of the prescribed methods, other small batches were put up in different ways—by using cheaper salt, leaving roes in, and other such modifications. These trials were failures without exception. About 80,000 fish were packed by the prescribed method and marketed the first year.

The successes and failures under these extremely adverse conditions tell us much about what could be expected under more favorable conditions. What succeeds under severe conditions will be a finer product under more favorable conditions, and what spoils under severe conditions will be an inferior product under conditions in which it does not actually spoil. It should be noted that the product prepared by this method is mild and sweet, approaching very closely fresh fish in eating qualities, if it has been properly soaked out.

SCOTCH-CURED HERRING.

The discussion in this paper so far presupposes the desirability of preserving as far as possible the flavor and eating qualities of fresh fish. The Scotch cure does not involve this supposition but aims directly at giving the cured fish a new and distinct flavor from partly decomposed or fermented blood, the purpose being the same as that governing the flavoring of cheese by ripening. The blood is not removed, the fish rather being allowed to cure in its own blood pickle, a distinctive flavor thereby being imparted. They are gibbed, rubbed with dry, fine salt and packed, more fish being added to make up for shrinkage, and shipped or stored in the original blood pickle. This method is suitable for cold but not for warm climates. Since, however, Scotch-cured herring come in a special class of fermented products where different motives and processes are concerned, the method will not be further discussed here.

MILD-CURED SALMON.

In the preservation of salmon by salting advantage is taken of the naturally cool temperatures prevailing in the Northwest, so that the extreme of dehydration by salt is not necessary. Even here no chances are taken, for in most instances the casks of mild-cured salmon are held in cold storage at about 38° F. The selection of salt is principally on the basis of fineness, because a fine-ground salt is necessary to stick to the moist fish, only that which sticks to the fish being used dry. It appears that in the mild curing of salmon some of the principles already referred to may be important. It was pointed out that calcium and magnesium salts combine with the fish protein to form a white, hard flesh. In the case of salmon it is desirable to preserve the red color which is contained in the fat, but the precipitation or coagulation of the otherwise transparent protein is in all probability the cause of whitening, which masks the attractive red color of the fat. Also, what was said about the loss of nitrogenous matter as a consequence of bruises applies to the mild curing of salmon.

BEHAVIOR OF FAT DURING SALTING PROCESS.

So far in this paper discussion has been limited to the behavior of the protein or meat constituents of fish. It will be found that fat is also of the greatest importance and requires very careful consideration and study. All fishes have some fat, but the quantity is variable from species to species, between individuals of the same species, and within a single individual from season to season. The distribution of fat is also different in different species of fish. Some fishes, such as herring, salmon, and alewives, contain fat well distributed throughout the body tissues. In others, such as cod and haddock, the fat is localized in some particular part of the body, as in the species mentioned the oil is contained in the lever, the flesh being almost entirely destitute of oil. For reasons that will be set forth later fat fish must not be exposed to the air because of untoward changes that air causes in the fat; but no harm is done to the protein constituents. Therefore fish which do not contain fat may be dried in air after they are salted.

In practice these differences are well recognized. In the case of cod and haddock, in which the muscle tissue is free from fat, the greater part of free water is extracted in the usual way by salt, later assisted by the pressure of piles or kenches, in which the lower layers are pressed by the weight of the upper layers in the kench, and finally by drying out of doors or in artificial drying tunnels. Fish prepared by this method are packed and shipped in the dry state, with advantages in saving of freight and simpler handling in general. In the case of mackerel and herring and such other fishes as have fat tissues the fish must at all times be carefully excluded from contact with air. If the fish are directly exposed to air for a time, the fish "rust"—that is, the fat becomes reddened and rancid—and the value of the fish for food is very greatly impaired. This rusting, especially of salt mackerel, is of immediate and pressing practical importance, for there is a regular waste of a large percentage of mackerel on our northeastern coast for no other cause than rustiness and rancidity. This aspect of the subject has not been investigated to any great extent, but there is just as much reason to expect valuable results to accrue from work on this problem as have accrued from the work already described.

Fats consist of a combination of glycerin with fatty acids. In the absolutely pure state, which is scarcely attainable, in fact, they would presumably be colorless, odorless, and tasteless. They usually contain a greater or smaller quantity of coloring matter dissolved, and under certain conditions the combination, glycerin-fatty acid, may be broken down, free glycerin and free fatty acid resulting. Free fatty acid has both taste and odor; in fact, our choicest fishes, such as salmon, shad, and mackerel, owe much of their peculiarly palatable flavor to the small amount of free fatty acid present. But many of the free fatty acids of fish oils readily oxidize on exposure to air and light, developing during the process a darker color and an unpleasant odor and taste which we call rancidity. Once fats have become rancid they can never be restored to their original sweetness.

What conditions promote rancidity? First, the fat must be decomposed or "split" into glycerin and free fatty acid. Next it must oxidize. Just as fish contain autolytic enzymes that decompose protein, so they also contain fat-splitting enzymes. These enzymes require moisture and warmth for their activities. Fat that has been removed from the tissue that produced it may be kept under proper condition for a long time, because only a small amount of fat-splitting enzyme goes with the oil, but when the fat is not removed from the original source all the enzyme is present and available to produce decomposition. So in salt fish the fat is in the presence of moisture and an abundance of enzyme, and the necessary warmth is usually present also, ideal conditions for decomposition. The fat having been split to fatty acid, there are two factors, so far as known—namely, air and light—which promote oxidation.

Some little study has been devoted to the effect of salts, such as sodium chloride and calcium chloride, on the splitting of fats, but not enough is known about the effect of these substances in concentration to be of any assistance. Whether or not bruises have the effect in promoting decomposition of fat that they have in promoting decomposition of protein is not known but would be well worth knowing, and here further investigation is certain to be of value. It is known that much of the fat in living fish is contained within inclosed cells, and that even the fattest fish is not greasy when fresh. But whenever the cells are ruptured by rough handling, decomposition or whatever cause, the oil escapes and is exposed to all the unfavorable influences of enzymes, moisture, air, and light, and the fish becomes greasy; eventually it will become rancid. And, further, oil escaped from the fish, being of a lower specific gravity than brine, at once rises to the top of the barrel and is lost as food.

All sorts of possible preventives of rust are practiced or suggested for practice—such things as impermeable barrels, air-proof covering over the liquid, a reducing substance in the brine to absorb the oxygen, cool, dark storage, and the like. There is, of course, much dissolved oxygen in the juice of the fish and in the brine and also considerable amounts of free oxygen occluded in the cavities of the fish to effect considerable rancidity, even if all outside air is excluded. This dissolved and occluded air can be removed by a vacuum pump, but this has never been tried commercially, so far as the writer is aware. Very little improvement can be expected until the problem has been thoroughly investigated by scientific methods. In the improved technique recommended by the Bureau of Fisheries in Florida complete covering of the salt fish by brine in tight barrels was specified.

REDDENING OF COD AND HADDOCK.

If cod and haddock escape rusting because of lack of fat, they are subject to another enemy perhaps as bad, namely, reddening, by which large quantities of cod and haddock are lost every year. For the past three years work has been conducted by the division of scientific inquiry of the Bureau of Fisheries on the causes of reddening and significant results have been obtained. The cause, in general, has been known for many years to be bacteria, but otherwise little has been known of the origin of these bacteria or of their peculiarities.

Briefly stated, the results of the work cited are as follows: The bacteria that cause reddening are of two distinct kinds—a spirochaete, which in colonies is pale pink, and a bacillus whose colonies are deep red. The two organisms grow in such close harmony that mixed colonies occur which vary in color from pale pink to deep crimson as the proportions of the two organisms present vary. The evidence points to the solor sea salts from the tropical and subtropical seas as the source of the infection. Solar sea salts, both American and foreign, are infected. Mined salts seem to be free from the infection.

Every species of bacteria is acclimated to some particular set of conditions, some of them almost incredible for living things. These red bacteria are accustomed to live and grow either on moist salt or very strong salt solutions. If bacteria are particularly resistant to some condition, as to strong salt in this case, it does not follow that they are likewise resistant to all severe conditions. It is the bacteriologist's business, by studying all the habits and peculiarities of the organism, to discover its weakest point where attack will destroy it. The strongest resistance of these bacteria, that against salt, is also the weakest, for it has been found that water less than 15 per cent saturated destroys them. Thus, the present indications are that the best and simplest remedy for the trouble is clean, fresh water and plenty of it. There is some evidence that may support the view that the usual impurities in salt, calcium and magnesium compounds, are essential to the growth and multiplication of these bacteria. The implication here is, of course, that pure salt itself would be a poor supporter of the bacteria. Of course, it would be futile to try to stop the reddening of cod as long as every shipment of salt brings new infection, and the butts, floors, buildings, and the surroundings at packing plants are heavily infected. Facts already given indicate also that for other reasons salt free from impurity is better. The results of the study of reddened cod only emphasize this advice.

The research on reddening should not, however, end here. We are again dealing with questions of permeability. The bacteria are adjusted to strong salt solutions, that is, the body fluid is of such concentration and their covering membrane is of such partial permeability that when surrounded by strong salt solution they live normally, but when water or weak brine surrounds them these relations are disturbed and they die. Probably water enters the cell in excessive quantity. It is known that the reddening does not attack fat fish. Perhaps the fat acts directly on the membrane, or indirectly by acting on the calcium and magnesium in the salt, to effect the disturbance.

RECOVERY OF BRINE.

Even crude salt now costs considerably more than coal. Yet the fish packers, who are usually very careful to economize in coal, are prodigal in the use of salt. Every hundred pounds of brine that goes overboard contain about 25 pounds of salt, to say nothing of the valuable nitrogenous matter that the brine has extracted from the fish. Considerable work has been done by the writer and his associates on the development of a process to recover salt and other substances of value from old pickle by precipitating the proteinaceous matter with sodium silicate. A trial plant was in use and under observation at an important fish-packing establishment for over a year but was not satisfactory under the circumstances. Brine pure enough for use was recovered, while a substance very rich in nitrogen was yielded as a by-product. This substance in the dry condition is nearly white and friable and contains enough nitrogen to command a handsome price as fertilizer if suitable for that purpose, but it may be more valuable for other uses. The method recovered brine, and for this reason some other method that would produce dry salt may be better. The experience gained in the work already done indicates that the recovery of valuable material from brine would not go well as a part of a small fish business but, having its own peculiar problems, would be more properly conducted as a separate business. In any event, this promising subject is commended to the chemists and engineers for study. We can not doubt that a few years will bring forth a complete solution of the problem of recovering things of value from brine that will make us wonder why we ever threw it away.

ACCESSORY CHEMICAL AGENTS AND OTHER FACTORS IN SALTING.

Various other chemicals are sometimes used in salt or along with it for various purposes. Some of these will be briefly discussed.

Saltpeter performs two functions in brine for the preservation of meat, namely, it combines with the red substance of blood, hemoglobin, which is unstable, to form a permanently stable red derivative, nitroso-hemoglobin. By virtue of its oxidizing power it may also oxidize hydrogen sulphide into sulphur dioxide and water; that is, a very foully odoriferous stuff to a substance which both bleaches and sterilizes. Saltpeter is, however, little used in curing fish, for the red color is undesirable, and hydrogen sulphide is rarely troublesome.

Boric or boracic acid is sometimes added to the final application of salt to dried salt cod. This is to prevent reddening. Undoubtedly it does do so, and undoubtedly most of it is removed from the fish when the latter is soaked up before cooking. Nevertheless, it seems that the end of this practice is not distant. Boric acid has long ago been condemned as a food preservative. With the comparatively small amount of scientific investigation that has already been done we have reason to hope that not only can reddening be prevented, but that by the general refinement and improvement of methods it will become unnecessary to use artificial preservatives to prevent reddening.

A method of promoting the preservation of fish by salt by the aid of sodium hypochlorite along with the salt has been patented. The original idea, it is understood, was to decompose the salt in sea water by electrolysis, sodium hypochlorite being formed. It was claimed that the sodium hypochlorite penetrates faster than ordinary salt. This substance contains some oxygen that may be given off to act as a sterilizing agent, and after the oxygen is given off ordinary salt or sodium chloride remains. What advantages the process possessed are not altogether apparent, for nothing appears to have come of it. It may be said, however, that sodium hypochlorite readily destroys urea, so that this substance might be advantageous in the preservation of grayfish and sharks but is unstable and must be used as soon as it is made.

The size and shape of the fish obviously have much to do with the time required for salt to penetrate through. Salt effects no preservation of parts until it reaches them. A thick fish may spoil, while a thin fish may be saved; hence the splitting of fish. Other methods of applying the salt to the inner parts of fish may be used, such as a needle syringe, whereby the brine is forced into the tissues, and compressed air, which is used to force brine into fish after the excess air has been removed from them in vacuo. It should also be possible to insert a needle in the gill arch and with pressure completely irrigate the whole system of arteries and veins of a fish, removing absolutely all the blood at one stroke without cutting the fish.

CONCLUSIONS.

The preservation of fish by means of salt is an excellent method. even in the crude and inexact manner in which the art has hitherto been practiced. The comparatively small amount of scientific research that has been done on the problems and principles involved has not only justified itself in practice but furnishes abundant grounds for the expectation that a great deal more of valuable results will follow further work. It is not mere guessing to say that when advantage is taken of all that is known of improved salting methods a fish nearly if not quite equal in edible qualities to fresh fish is obtained, and in some cases the quality is decidedly improved by salting.

There is every reason to expect a good future for the salt fish industry, but progress must be made. Preservation by this method is eminently practicable, simple, and reliable for holding and transporting our sea fishes to the inland population.

SUMMARY.

1. A discussion of the principles involved in the preservation of fish by salt has been presented.

2. Salt possesses no inherently peculiar preserving qualities, but preserves food by extracting water.

3. The principle by which salt (and other soluble substances) in concentrated solution extracts water is called osmosis. Osmosis is the passage or interchange of liquids and solutions through membranes which are more or less permeable. The permeability of cell membranes in fishes appears to be affected by high and low temperatures. The presence in or absence from the salt of certain impurities, notably calcium and magnesium compounds, the treatment of the fish, and the staleness of the fish, are factors which govern the permeability and have an important bearing on the preservation of fish by salt.

4. Calcium and magnesium compounds in addition to retarding penetration cause a whitening and hardening of the fish. There are chemical reasons for looking upon this whitening and hardening by these compounds as undesirable.

5. The flavor of fish is often altered by the salting process. Calcium salts retained in the tissue increase the salty taste and make necessary a prolonged soaking out. Undesirable flavors of fishes from muddy waters may sometimes be removed by salting the fish.

6. Salt applied dry penetrates the fish more rapidly and effects a quicker cure with less danger of spoilage in warm weather.

7. There is a very material loss of protein material from fish during the salting process. This material probably arises from the decomposition products ordinarily unable to pass out of the cells but which are digested by autolysis, an internal destructive process.

8. Autolysis is increased by crushing, bruising, rough handling, pewing, elevated temperatures, low temperatures followed by a rise, and, in general by factors that increase cell permeability. It is

retarded or arrested by continued low temperatures, sufficiently high temperatures, and by salt.

9. The damage done by autolysis appears to be in large part preventable.

10. Fish containing blood, or otherwise not well cleaned, spoil at a lower temperature than those thoroughly cleaned and freed from blood. Thoroughly cleaned fish may be salted at from 90 to 100° F. if pure salt is used.

11. A method of curing fish embodying the improvements cited was tried in Florida on a small commercial scale with gratifying success.

12. Scotch-cured herring develop a peculiar flavor which is derived from the fermented or otherwise altered blood. This method has for its aim an alteration to suit particular tastes, while other methods of salting discussed aim at the preservation of the fresh qualities of fish.

13. There are reasons for expecting that the improvements made in the salting of other fish, particularly those which depend on the use of a very pure salt, will find application in the mild curing of salmon.

14. Fats undergo certain changes after the fish is salted, resulting in a condition known as "rusting." Rusting consists of oxidation of fat after the latter has been split into free fatty acids. This splitting is caused by tissue enzymes in the presence of warmth and moisture. Oxidation is brought about through the agency of light in the presence of water. While rusting causes large losses of fish, the means of preventing it, such as tight barrels, air-tight covering, and cool dark storage, are not very satisfactory. The problem demands further investigation.

15. Fishes whose flesh is not fat and therefore not prone to rust are subject to damage by reddening. Reddening is caused by two organisms, a spirochaete and a bacillus. They may be destroyed by fresh water or live steam. They originate probably in solar sea salt and are apparently not found in mined salt or other purified American salt.

16. Some work has been done toward the development of a process for recovery of salt and other valuable materials from brine. There are a number of promising possibilities which should make this an attractive field for chemists and engineers.

17. Certain substances are sometimes used as adjuncts in salting fish. Saltpeter preserves a pink color and neutralizes hydrogen sulphide. Boric acid is used for preserving cod against reddening. Sodium hypochlorite has been proposed as advantageous in conjunction with salt. It may be produced electrolytically from sea water.

18. The size and shape of the fish influences the rate of penetration of salt into it. Certain mechanical methods of forcing brine into large fish may be advantageous.

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